

Milk by-products in either the fresh or dried forms have been used extensively in bakery products to improve their functional and nutritional characteristics. The connotation that milk is a quality food product undoubtedly contributes to its continued use in bakery products.

Even though milk improves many of the characteristics of doughs and breads, Larsen *et al* (1) reported that even when properly heated, it can still slightly depress volume of breads made by the straight dough process. They also reported that serum proteins, when properly heated and when adequate levels of bromate were used in the formula, had no adverse effect on loaf volume. Casein produced some loss of volume, but lactose produced the most. No explanation was advanced for the volume-depressing effects of lactose that were somewhat overcome by the addition of potassium bromate. Generally, longer proof times are required to correct slight to moderate loaf volume depressions in breads. Extensive loaf volume depressions in bakery products are associated with poorer quality and less palatable products.

Barham and Johnson (2) showed that sucrose levels above 4 per cent in sponge and dough systems decreased the specific volumes of breads and increased times to proof to height of their doughs. Others (3,4) have also documented this effect. This is generally conceded to be due to the osmotic activity of higher levels of sugar. Likewise, salt inhibits yeast action due to osmosis. About one part of salt is equivalent to six parts of sucrose or dextrose (5). Bohn (6) has shown that only 30 to 40 per cent of the normal level of the 7-8 per cent added sucrose is actually fermented in sponge doughs; the rest is inverted by yeast and remains for sweetening and browning reactions.

Since it was observed in this laboratory that under defined conditions of fermentation, proofing and baking, milk solids and whey solids depress the loaf volume of sponge breads, it was thought worthwhile to reinvestigate the role of their lactose content in volume depression. Because nonfat dry milk (NDM) contains 50-51 per cent lactose, sweet whey solids 72-74 per cent and Cottage cheese whey solids 64-66 per cent, it was decided to study the sponge bread volume response of these substances at equal lactose levels as compared to an equivalent amount of pure lactose.

In this study, CO₂ production measurements were made of mixed doughs containing these ingredients, as well as farinograph analyses of the dried milk. Means are suggested for

Effect of the Lactose in Nonfat Dry Milk and Cheese Whey Solids on Sponge Bread Loaf Volume and Yeast Activity

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overcoming some of the volume-depressing effects of lactose and lactose-containing products. Also, a possible mechanism of lactose action in doughs is postulated.

Materials

Flours. — A commercial hard red winter wheat flour (HRW, 11.7 per cent protein) that was malt supplemented and bleached, and a hard red spring wheat flour (HRS, 14.6 per cent protein) that was malt supplemented, bleached and bromated were used.

Dry Milks. — All fluid milk or milk by-products were dried in the Dairy Products Laboratory plant. Sweet cheese whey was obtained from milk processed for Cheddar cheese at the U.S.D.A. Dairy Products Research Building, Beltsville, Md. These fluid products were heated to 85°C (185°F) for 30 minutes prior to concentrating to 40 per cent total solids and drying. Cottage cheese whey was obtained from a commercial source and preheated to 91°C (195.8°F) for 30 minutes prior to condensing to 45 per cent total solids and foam

spray drying with CO₂ injection (7,8).

Table I lists the analysis of these dry products.

Miscellaneous. — Freshly delivered bakers' compressed yeast was held at 6°C (42.8°F) for no longer than one week prior to use. A single lot of dry yeast was used and kept in a sealed jar at 6°C after removal from the can. U.S.P. grade lactose and bakers' grade salt and sugar were used.

Methods

Baking. — The A.A.C.C. standard method (9) for sponge and dough was generally followed, with modifications as shown in **Table II**. When desired, NDM and cheese wheys were added dry at the sponge and dough stage at a 3 per cent lactose-containing level. Doughs were mixed at optimum absorption (using the farinograph as a guide) for optimum mixing times (as judged by the baker), using previously determined optimum bromate levels. Lactose did not increase bromate requirements. Exactly 500 gm of dough was scaled off in all tests. Doughs were proofed for 60 minutes or to five-eighths inches above the pan

Table I
Analysis of Dried Lactose-Containing Products

	% Protein	WPN* mgm/g.	% Lactose	% Moisture	% Lactic Acid
Nonfat dry milk	36.4	1.0	51.2	4.4	—
Sweet whey	11.0	3.2	73.0	2.8	1.8
Cottage cheese whey	11.5	2.8	65.6	2.4	7.1

*Whey protein nitrogen

Table II
Sponge Dough Formula

	Sponge %	Dough %
Flour HRS	70	30
HRW	65	35
Water HRS	44	Variable
HRW	38	Variable
Dry lactose-containing products	—	Variable
Sugar	—	4.5-10.5
Shortening	—	3.0
Salt	—	2.25
Compressed yeast	2.0-3.0	—
or		
Dry yeast	1.2	
Bromated yeast food	0.5	
or		
Bromate-free yeast food	0.5	
Malt	0.5	
Dough temperature	76 ± 1°	80-81°F
Fermentation	4 hrs. at 86°F and 88% RH	40 min. floor time 86°F, 15 min. int. proof. Proof 100°F 90% RH
Bake		415°F — 25 min.

Table III
Analysis of Variance of HRS Breads

DF	F ratios		
	Cc Loaf Volume/100 g Proof to Height	Proof to Time	Minutes Time to Proof to Constant Height
(M) Milks 2	35.1**	91.5**	108**
(S) Sugars 2	51.0**	528**	546**
Yeasts 2	3.99**	132**	256**
M x S 4	1.48	2.54*	5.45**
	Error Mean Square		
	284	371	3.2

*Significant at 5% level.

**Significant at 1% level.

as measured by the template. When dry yeast was used, 1.5 per cent additional absorption water was used.

Farinograph. — A model PL-2H Farinograph, equipped with a bowl set at 30°C (86°F), was used. The

mixer rotated at 63 rpm. Using the 300 gm constant flour weight procedure (9), sufficient water was added to a blend of flour, milk solids, and 2 per cent salt to center the curve on the 500 B. U. line.

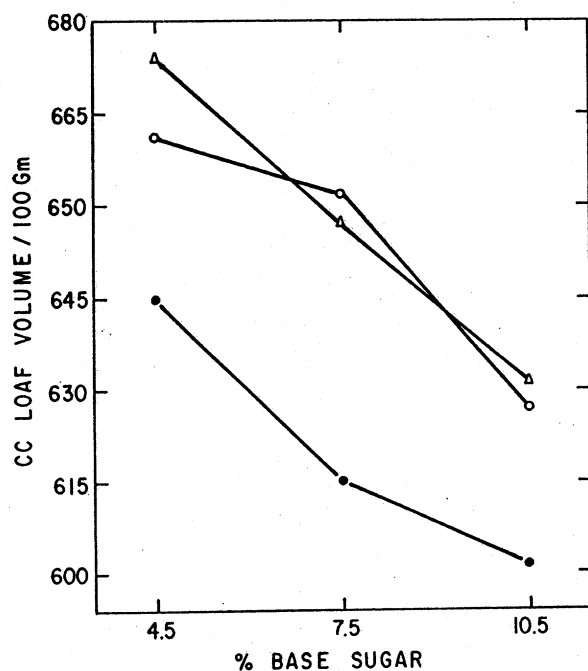


Figure 1: Effect of proofing to 5/8" height on loaf volume/100 g using HRS with 3 levels of yeast, 3 levels of base sugar and 3 milk products. Open circles represent control, closed circles 3% lactose and triangles 6% NDM.

Pressuremeter. — Carbon dioxide production studies were run at 30°C (86°F). Exactly 17.30 gm of dough containing all the formula ingredients was taken out of the mixer and scaled into 2-oz. wax paper cups which, in turn, were placed inside standard volume mercury manometer pressuremeter vessels. The vessels were held five minutes, degassed, and measurements were taken. Readings were recorded at two hours. This is equivalent to the time this dough would be proofed before being placed in the oven. For the milks used, as well as the control doughs, the rate of gas production, as measured by the ratio of two to one hour values, was constant. Carbon dioxide retention studies were run on 8-g. dough pieces according to the method of Barham and Johnson (2). The average carbon dioxide production of doughs held two, two and one-half and three hours over 23 per cent NaOH was compared to those held over 23 per cent NaCl. From these ratios, the per cent carbon dioxide retention values were computed. For any one sample, these retention values at the three times had an average standard deviation of ±1.4 per cent from the average value for HRW flour doughs and ±0.6 per cent from HRS flour doughs. Barometric readings were recorded each day, and all carbon dioxide pressures were corrected to 760 mm standard pressure, although this correction changed the values only very slightly. Duplicate analyses were made to obtain retention values.

Statistics

Analysis of variance data is reported in terms of F ratio to determine significance. The F value is expressed as the ratio of the mean square of a main factor, which measures the variation due to a main effect, divided by the mean square for the error term, which is a measure of the variation that is inherent in the testing procedure. The higher the ratio, the more significant the results. The factorial analysis also permits an assessment of significance of interaction between factors. In this paper, the response between milk products at 10.5 per cent sugar can be shown under some circumstances to be significantly different from the response at 7.5 and 4.5 per cent sugar. F ratios are expressed as a 5 per cent or 1 per cent confidence level by respectively placing one asterisk and two asterisks after the ratio. A 5 per cent confidence level implies that, on the average, the means would be different for 95 per cent of similar observations made, and at a 1 per cent confidence level, for

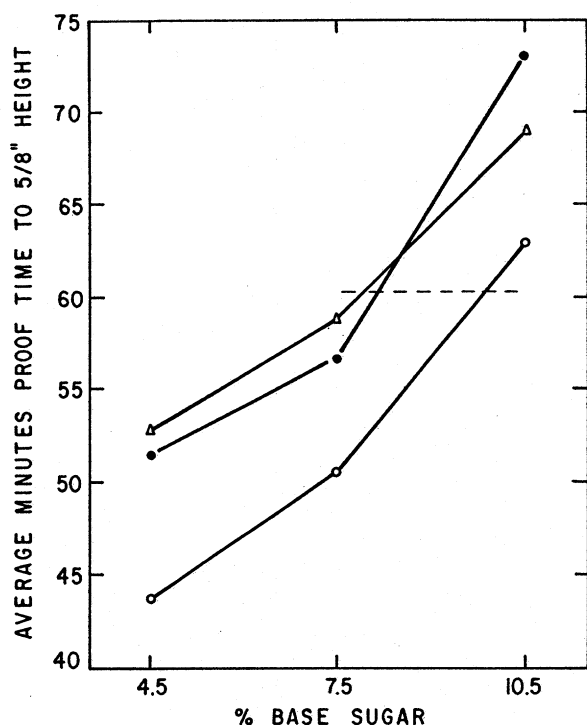


Figure 2: Average minutes time to proof to 5/8" height using HRS flour with 3 levels of yeast, 3 levels of base sugar and 3 milk products. $S \times M$ interaction difference at 5% level = 2.86 minutes. Open circles represent control, closed circles 3% lactose and triangles 6% NDM.

99 per cent of similar observations made. With HRW doughs, significance was determined by use of the standard deviation at the 5 per cent level, calculated from the ranges (10). In these instances, the significant difference (D) was determined

by the formula $\frac{2S\sqrt{a}}{\sqrt{n}}$ where S is the

standard deviation, a is the numerical rank of means in the array of data,

and n equals the number of observations or replications.

pH.—pH determinations were made by inserting the electrodes of a Beckman Zeromatic pH meter directly into the doughs or into suspensions of 4.5 g bread in 30 ml water.

Miscellaneous.—Per cent moisture of powders was determined by toluene distillation (11), nitrogen by the micro Kjeldahl procedure, and undenatured whey protein nitrogen (WPN) by the method of Leighton (12). This

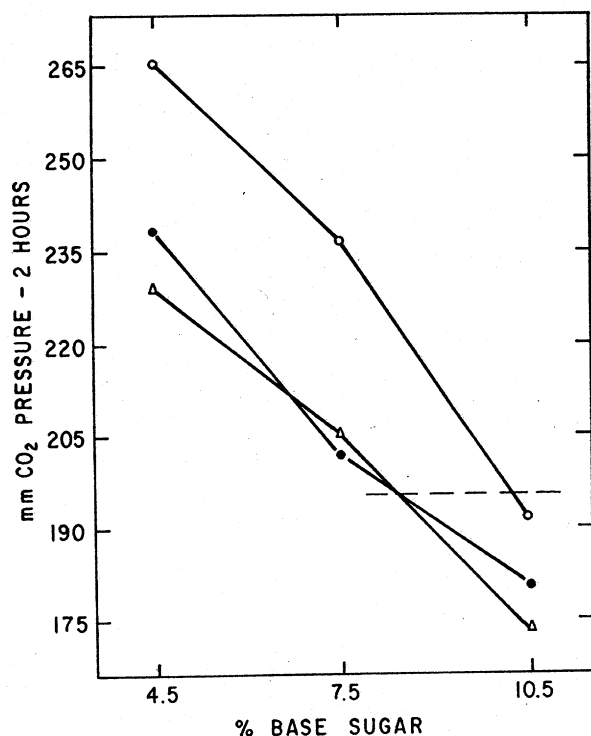


Figure 3: Two hour mm CO₂ pressures of HRS flour doughs containing 2.5% compressed yeast with 3 levels of sugars and 3 levels of milk products. $S \times M$ interaction difference at 5% level = 13.2 mm. Open circles represent control, closed circles 3% lactose and triangles 6% NDM.

method was modified by Guy *et al.* (13) for determinations of WPN in Cottage cheese whey. Lactose was determined colorimetrically, using the Folin-Wu method (14).

Results and Discussions

HRS flour.—Statistically designed studies were made with sponge breads, using 4.5, 7.5 and 10.5 per cent compressed yeast and, with each combination, no milk, 6 per cent NDM, or 3 per cent lactose (designated as milks). Additionally, two-hour carbon dioxide pressures of nine freshly mixed doughs, taken at the sponge and dough stage and containing 2.5 per cent compressed yeast, were made. An increase in absorption of 6 per cent water was used in doughs containing 6 per cent NDM. Two doughs were mixed for each factor studied, yielding two loaves of bread per dough.

Table III shows that the F ratios of the volumes obtained at 60 minutes constant proof time and the minutes time to proof to five-eighths inches height are relatively comparable. To some extent, proofing to height minimizes the volume effects. All factors reported in this table, except one, are significant at least at the 5 per cent level. When doughs containing lactose are proofed to constant height their volumes are lowered, but not those containing NDM (**Figure 1**). However both lactose and NDM lengthen proof time to a similar extent (**Figure 2**), depress carbon dioxide productions equally (**Figure 3, Table IV**), and do not modify retention of carbon dioxide by doughs (**Table V**). Both lactose and NDM depress the volume of bread made from doughs proofed for 60 minutes, but lactose depresses the volume the most (**Figure 4**). Evaluation of these data indicates oven spring characteristics favor NDM-containing doughs more than doughs containing only added lactose. Thus, factors other than lactose are operative in volume responses of NDM-containing doughs. It is noted in **Figure 4** that the volumes of breads made with 7.5 per cent sugar doughs containing 3 per cent extra sucrose or 3 per cent extra lactose are much the same (dotted line), even though the sucrose-containing doughs show lower carbon dioxide pressures (**Figure 3**) and significantly longer proof times (**Figure 2**). This is again indicative of the poor oven spring characteristics of doughs supplemented only with lactose. It can be seen in **Figure 4** that, as a result of the significant interaction of the loaf volume with milks and sugars, added lactose or NDM in 4.5 per cent sugar

Table IV

Analysis of Variance of mm CO₂ Pressure of HRS Doughs Held Two Hrs. at 30°C.

	DF	Mean Squares	F Ratios
(M) Milks	2	2080	65.0**
(S) Sugars	2	8800	275**
M x S	4	126.5	3.96**
Error	16	32	—

**Significant at 1% level.

doughs causes less bread volume depression than in 7.5 per cent or 10.5 per cent sugar doughs.

HRW Flour — Comparison of Dry vs. Compressed Yeasts. — Since dry yeasts are known to be highly resistant to the osmotic effects of sugars, baking studies were conducted using this yeast. The effect of dry and compressed yeast on loaf volume and carbon dioxide production was investigated using 3 per cent lactose (L), 3 per cent additional sucrose (S), NDM, and sweet whey (SW) or Cottage cheese whey (CCW) in amounts sufficient to provide 3 per cent lactose. An additional absorption of 4.5 per cent water was used with 6 per cent NDM and 2 per cent less water was used with Cottage cheese whey. At least four doughs yielding two loaves of bread per dough were baked on separate days. The carbon dioxide pressure measurements of doughs were run in duplicate. **Figure 5** shows that all materials significantly depress bread volume and carbon dioxide pressures, using a constant proof time and 7.5 per cent sugar. With all these substances, except extra sucrose, dry yeast causes less volume depression and carbon dioxide inhibition than compressed yeast. With dry yeast, the addition of 3 per cent sucrose causes significantly more loaf volume and mm CO₂ depression than 3 per cent added lactose. However,

Table V

CO₂ Retention of Doughs With Different Lactose-Containing Products

Dry Products	% CO ₂ Retention	
	HRW Flour	HRS Flour
Control	75.2	73.8
3% Lactose	77.5	74.1
3% Extra Sucrose	76.1	73.5
4.2% Sweet Whey	74.1	—
4.6% Cottage Cheese Whey	77.2	—
6.0% NDM	73.8	74.6
For $\alpha = 2$	D = 1.6	D = 0.7
$\alpha = 4$	D = 2.3	D = 1.0
$\alpha = 6$	D = 2.8	—

α = numerical rank of means

D = significance differences at the 5% confidence level

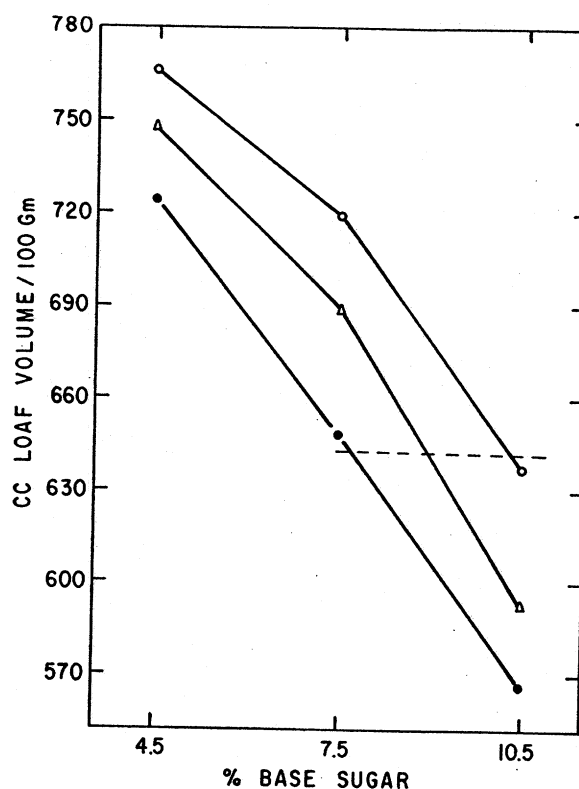


Figure 4: Effect of proofing for 60 minutes time on cc loaf volume/100 g using HRS flour with 3 levels of yeast, 3 levels of base sugar, and 3 milk products. $S \times M$ interaction difference at 5% level = 21 cc. Open circles represent control, closed circles 3% lactose, triangles 6% NDM.

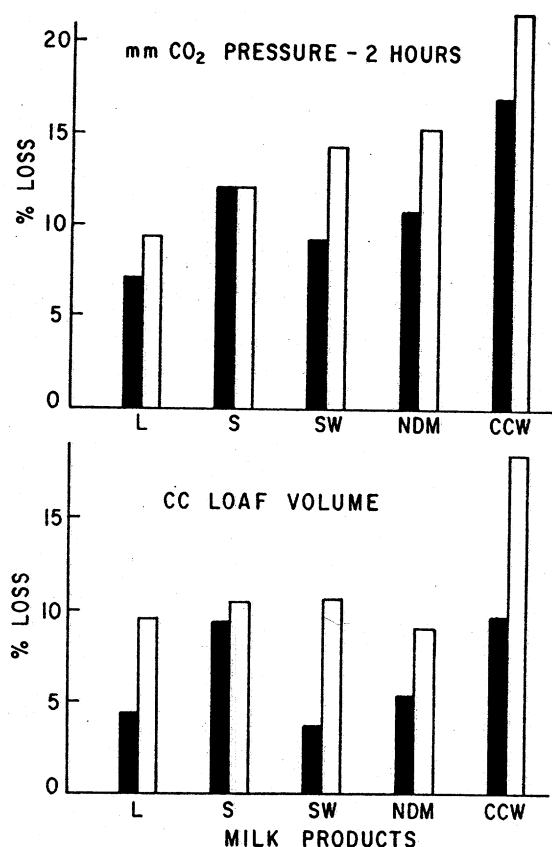


Figure 5: Effect of milk products and two yeasts using HRS flour doughs containing 7.5% base sugar on % loss of loaf volume in cc/100 gm from doughs proofed 60 minutes and % loss of mm CO₂ in 2 hours. Shaded bars represent dry yeast and clear bars, compressed yeast.

% Significant Difference at 5% Level for

	mm CO ₂ Pressure		cc Loaf Volume	
	Shaded	Clear	Shaded	Clear
$\alpha = 2$	3.1	3.5	2.6	2.3
$\alpha = 6$	5.4	6.2	4.6	4.0

Table VIII demonstrates that the addition of increasing levels of lactose increases the average proof time and decreases loaf volumes of breads made from HRS flour and again illustrates the yeast-inhibiting powers of additional lactose. In these studies, 7.5 per cent sugar, 2.5 per cent compressed yeast and 2.25 per cent salt were used.

Summary and Conclusions

This study shows that lactose depressed both the bread loaf volume and carbon dioxide production of doughs made from HRW and HRS flours. It is postulated that lactose, as well as extra sucrose, inhibits carbon dioxide production of doughs through osmotic effects. When adding the normal or 7.5 per cent level of sugar in the formula, the addition of 3 per cent extra sucrose decreases carbon dioxide production and increases proof time more than 3 per cent extra lactose does. This is because additional sucrose is rapidly inverted by yeast to its constituent monosaccharides, glucose and fructose. This splitting doubles the effective molar or osmotic potential of sucrose. Since lactose is not hydrolysable (15), no change in osmotic potential can occur with this additive. However, data collected using the 4.5 per cent level of sucrose indicated that the effective osmotic response to 3 per cent additional sucrose, as measured by proof time increases and carbon dioxide production, is not significantly greater than that of added lactose. Presumably this is because the osmotic effects of additional sugar are not so pronounced over this lower total sugar range.

At equal lactose-containing levels, NDM, sweet whey and Cottage cheese whey depressed volumes and carbon dioxide production and increased proof times. This action varied, to some extent, with flour, types of dairy ingredients, and types of yeast and formulae used. At constant proof times, NDM depressed volume of bread made from HRS flour doughs less than that made from HRW flour doughs. Because of its lactic acid content, Cottage cheese whey depressed volumes significantly more than did sweet whey. Both the loaf volume and carbon dioxide production depressant effects of lactose, NDM, and cheese wheys, under controlled proofing schedules, can be minimized by employing dry yeast instead of compressed yeast. In many instances, both the loaf volume and carbon dioxide production depressant effects can be minimized with these materials by employing lower levels of sugar in the doughs. Also, proofing to

Table VI
Effect of Different Lactose-Containing Products on pH of Doughs and Breads Made with HRW Flour

Dry Products	pH Freshly Mixed Sponge and Dough	pH Bread
Control	4.85	4.75
3% Lactose	4.85	4.80
3% Extra Sucrose	4.85	4.85
4.2% Sweet Whey	5.00	5.00
4.6% Cottage Cheese Whey	4.70	4.75
6% NDM	5.50	5.50
4.2% Sweet Whey + 0.16% lactic Acid	4.60	4.70

height instead of time, as is commonly done in the baking trade, tends to minimize volume depressive effects. These facts indirectly suggest that the lactose of NDM and cheese wheys, although probably not the only factor involved, can be significant in the loaf volume depressant action. To more completely elucidate the role of dairy ingredients in sponge bread baking, similar studies with milk salts and milk protein should be undertaken.

Table VII
Farinograph Absorption of Flours Containing 2% Salt Plus Lactose-Containing Products

Product	% Absorption "as is" Basis	
	HRW Flour	HRS Flour
Control	59.7	61.7
3% Lactose	59.0	61.3
3% Sucrose	59.3	61.7
4.2% Sweet Whey	59.3	—
4.6% Cottage Cheese Whey	57.7	—
6% NDM	65.7	69.0
4.2% Sweet Whey + 0.16% lactic acid	57.0	—

This study suggests that lowering the lactose and acid contents of whey should be beneficial in overcoming volume depressing effects. To this end, electrodialysis and reverse osmosis should offer means of upgrading the baking potential of wheys, as well as yielding a product with a higher level of nutritious protein.

Table VIII
Effect of Different Levels of Lactose on Minutes Proof Time and Loaf Volume Using HRS Flour

% Lactose	Minutes Proof to height	Av. cc Loaf Volume 100 g (Proof height)
0	51	646
1.5	54	636
3.0	60	623
4.5	64	614

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